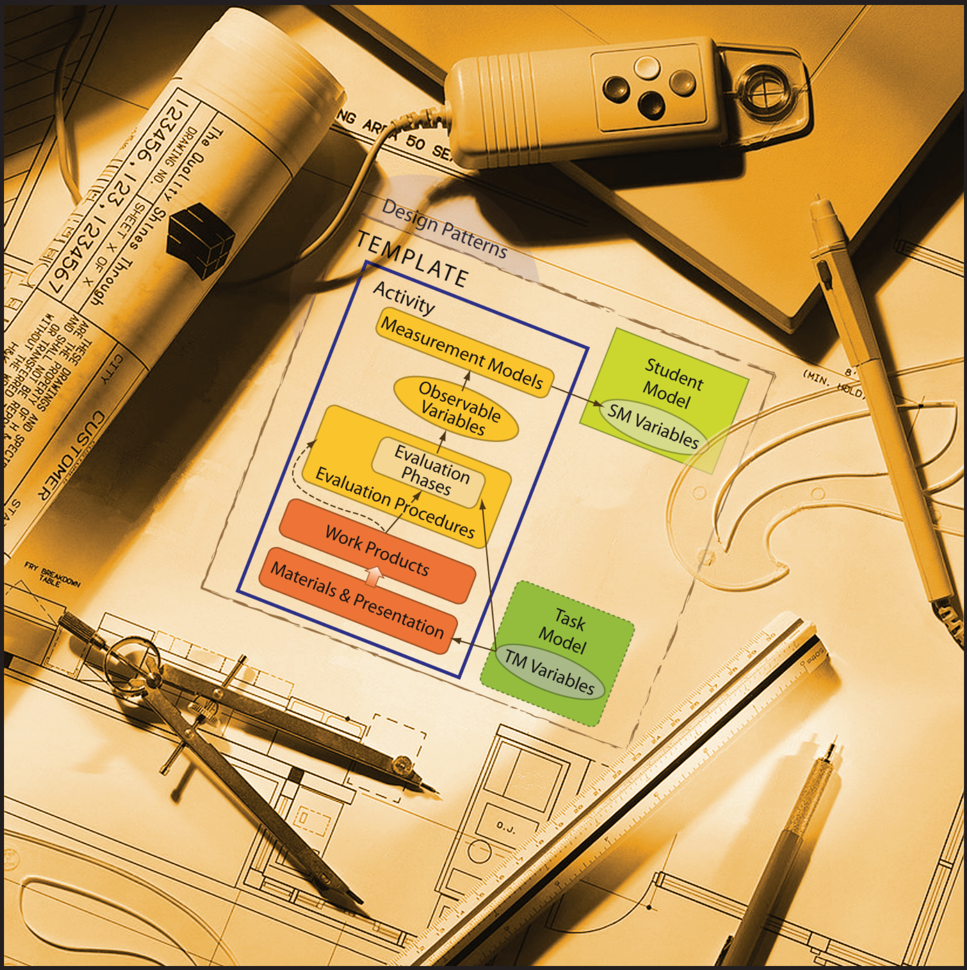

Large-Scale Assessment Technical Report 2| May 2009

A Design Pattern for Observational Investigation Assessment Tasks

Project: Application of Evidence-Centered Design to State Large-Scale Science Assessment

Robert J. Mislevy, Min Liu, & Youngmi Cho University of Maryland; **Dennis Fulkerson & Paul Nichols**, Pearson; **Daniel Zalles, Ron Fried, Geneva Haertel, Britte Cheng, Angela DeBarger, & Serena Villalba** , SRI International; **Alexis Mitman Colker,** Consultant; **Kathleen Haynie**, Kathleen Haynie Consulting; **Larry Hamel**, Codeguild, Inc.

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APPLICATION OF EVIDENCE-CENTERED DESIGN FOR LARGE-SCALE STATE SCIENCE ASSESSMENT

TECHNICAL REPORT 2

A Design Pattern for Observational Investigation Assessment Tasks

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Abstract

The significance of inquiry skills is widely acknowledged in science practice across many areas. Unlike experimentation, another form of inquiry skill, observational investigation, has been much ignored in science education and thus science assessment. Drawing on research development in assessment design, this paper provides a design pattern to help assessment designers create tasks assessing students' complex scientific reasoning skills in observational investigation. This design pattern lays out considerations regarding targeted knowledge and skills in this inquiry process, characteristics of situations in which student can evidence that skill, and ways of evaluating their work with specific examples.

1.0 Introduction

Recent reform efforts in American science education emphasize inquiry skills that are vital in scientific practice[4]. Students need to be able to conduct investigations in order to deeply understand scientific models and theories, as well as the terms, concepts, and procedures they are grounded on (Smith & Reiser, 2005). Much science education research has been done on teaching and assessing students' skills in *experimentation*, which is considered as the primary means of inquiry in science. However, another form of inquiry, *observational investigation* that is more appropriate in other situations frequently arising in many areas of science such as astronomy and geology, has received far less attention (Smith & Reiser, 2005; Tomkins & Tunnicliffe, 2001). Consequently, exploring how to assess students' capabilities in observational investigation validly and efficiently is a topic of some importance.

This report addresses the topic of designing tasks that provide evidence about students' capabilities in observational investigation, in a way that supports such efforts across science areas and levels of education. It draws on research on assessment design carried out under the evidence-centered design approach (ECD; Mislevy, Steinberg, & Almond, 2003; Mislevy & Haertel, 2006). Specifically, it presents an assessment design pattern (Mislevy, et al., 2003) for assessing scientific reasoning skills in observational investigation. Design patterns are a tool developed in the Principled Assessment Design for Inquiry (PADI) project, supported by the National Science Foundation (NSF). The particular design pattern was constructed for the project "Application of Evidence-Centered Design to State Large-Scale Science Assessment," also supported by NSF to apply ECD in the context of a state-level large-scale accountability assessment in science. It was developed collaboratively by researchers, test developers, and content experts from SRI International, the University of Maryland, Pearson, and the State of Minnesota. It is being applied in operational

[4] Inquiry and the National Science Education Standards at www.nap.edu

work by the committees of Minnesota item-writers (mostly current or retired Minnesota science teachers) who, with coordination, training, and support from Pearson and the staff of the Minnesota Department of Education, create the Minnesota Comprehensive Assessment (MCA-II) in science.

The following section sets the stage for the Observational Investigation design patterns with background on ECD and PADI, then on observational investigation. The attributes of the design pattern are then discussed in detail and illustrated with example tasks.

2.0 Evidence Centered Design and Assessment Arguments

In order to show how design patterns support the authoring of tasks that assess students' capabilities in observational investigation, we briefly review the ECD framework and Toulmin's (1958) structure for evidentiary argument and its relation to the design pattern.

2.1 Evidence–Centered Assessment Design

Evidence-centered assessment design (ECD) provides principles, patterns, and examples to guide the task designers through articulating the theoretical foundation to the operational work of assessment development (e.g., item writing, directions, test administration, scoring procedures) (Mislevy, Almond, & Lukas, 2004). This structured framework explicates, and thus enables designers to more efficiently control the elements and underlying processes of assessment design.

ECD lays out the structure/process of an assessment design in terms of five layers, which conceptualize different work being carried out by different experts or parties at different stages of design process. Figure 1 summarizes the ECD layers in a way that reflects successive refinement and reorganization of knowledge about the content domain and the purpose of the assessment, from a substantive argument to the specific elements and processes needed in its operation.

As the first stage in assessment design, *Domain analysis* concerns marshaling substantive information about the domain and it leads us to understand the knowledge, skills, and abilities people use in a domain of interest, the representational forms of them, characteristics of good work, and features of situations. All of this information has important implications for assessment design, but most of them are neither originally created nor presented in the structure of argument. The cognitive research on observational investigation discussed below and the identification of relevant Minnesota Academic Standards in Science[5] are examples of work in Domain Analysis.

In the *Domain Modeling* layer, information identified in Domain Analysis is organized along the lines of assessment arguments. Without getting tangled in the technical details of assessment design and psychometric models, this layer directs researchers to clarify what is meant to be assessed and how and why to do so. A tool for supporting work in *Domain Modeling*, design patterns (DP), helps the assessment designer think through the key elements of an assessment argument in narrative form. Details of design patterns will be given later in a section that reviews the attributes of a design pattern and in a section that discusses in detail the contents of the design pattern for assessing students' proficiencies with regard to observational investigations.

While the other three remaining layers of the ECD framework are less directly related to the purpose of this design pattern, they are introduced for the sake of completeness. The reader is referred to Almond, Steinberg, and Mislevy (2003) and Mislevy and Riconscente (2006) for further discussion on these layers.

The *Conceptual Assessment Framework (CAF)* concerns technical specifications for operational elements. An assessment argument laid out in narrative form at the Domain Modeling layer is here expressed in terms of coordinated pieces of machinery such as measurement models, scoring methods, and delivery requirements. The commonality of data structures and reusability of the central CAF models offer opportunities to bring down the costs of task design, which is especially important for computer-based tasks.

The fourth layer, the *Assessment Implementation* includes activities carried out to prepare for the operational administration for testing examinees, such as

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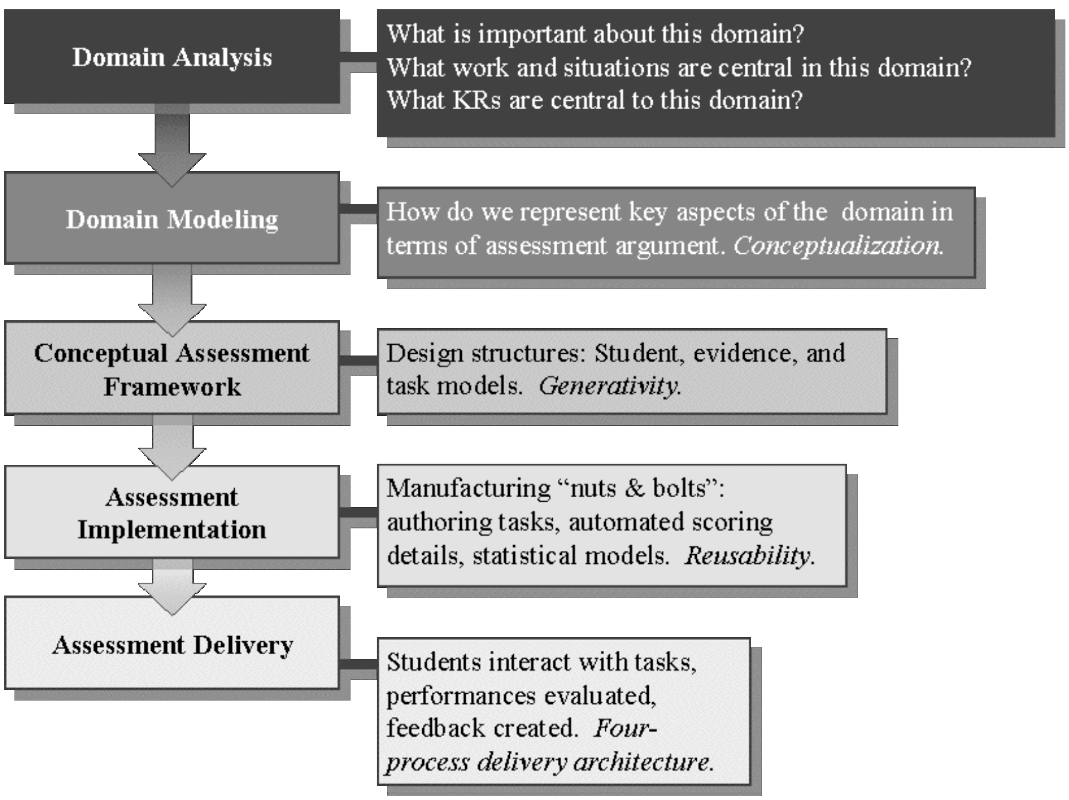
5 http://education.state.mn.us/mdeprod/idcplg?IdcService=GET_FILE&dDocName=000282&RevisionSelectionMethod=latestReleased&Rendition=primary

authoring tasks, calibrating items into psychometric models, piloting and finalizing scoring rubrics, producing assessment materials and presentation environments, and training interviewers and scorers, all in accordance with the assessment arguments and test specifications created in previous stages.

The final layer, Assessment Delivery, includes activities in presenting tasks to examinees, evaluating performances to assign scores, and reporting the results to provide feedback or support decision making.

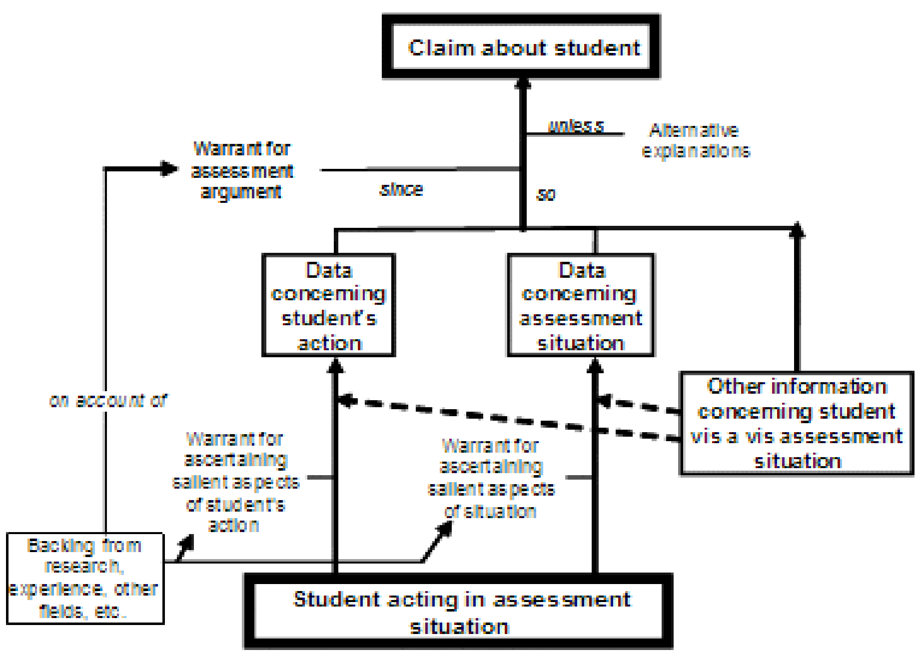
Figure 1. Layers of Evidence-Centered Design for Educational Assessment



2.2 Assessment Arguments

An educational assessment can be viewed as an evidentiary argument that make inference from what student say, do or make in task settings, to claims that what they can know, can do, or accomplish more generally (Messick, 1994). Toulmin (1958) provides a useful schema for the general structure of argument. Figure 2 adapts his terminology and representations to educational assessment arguments (Mislevy, 2003, 2006). In this diagram, a series of logically connected claims are supported by data via warrants, subject to alternative explanations. The *claims* concern aspects of proficiency that students possess, i.e., what they know or can do in various situations. *Data* are required to support claims. In the case of assessment, data consist of students' behaviors in particular task situations, the features of task situations, and other relevant information about the relationship between the student and the task situation (e.g., personal or instructional experience; in the case of the MCA-II, science content from benchmarks at grades at the level lower than the assessment at hand, such as presuming Grade 5 benchmarks for the Grade 8 test). The arrow going to the claim represents a logically reasoned inference by means of a *warrant*. The *warrant* posits how responses in situations with the noted features depend on proficiency. The primary source of the warrants is the underlying psychological conceptualization of knowledge and its acquisition, i.e., a psychological perspective, which shapes the nature of claims that assessments aim to make and of the data that are needed to evidence them. *Alternative explanations* for poor performance are deficits in the knowledge or skills that are needed to carry out a task but are not focal to the claims.

Figure 2. A Toulmin argument diagram for assessment arguments



2.3 Attributes of a Design Pattern

Figure 2 indicates the structure of an assessment argument, but not its content. A design pattern can help task designers to think through substantive aspects of the assessment argument. In this way, design patterns fill the gap between academic content standards and specific assessments tasks. Although creating a design pattern may seem to be a time-consuming job, it can save time and energy in the long run by capturing design rationales in a re-usable and generative form. Consequently a design pattern can smooth the transition to more technical work in the next layers, by serving as a foundation for many tasks that must address key knowledge and skills in the domain. Furthermore, the experience and thinking captured in a design pattern provides shared information across applications, such as large-scale and classroom assessment, and assessment, instruction, and research. For these reasons, Mislevy and Haertel (2006) identified design patterns as a primary leverage point to improve design efficiency and validity in large-scale assessments.

A design pattern consists of attributes that can be associated with components of an assessment argument, as shown in Table 1. They correspond to an assessment argument by identifying the knowledge, skills, or abilities (KSAs) about which assessors want to make a claim, the kinds of data that provide evidence about student acquisition of that KSA, and features of task conditions that can enable students to produce the evidence.

Table 1: Attributes of a Design Pattern[6]

Attribute	Definition	Assessment Argument Component
Name	Short name for the design pattern	
Summary	Brief description of the family of tasks implied by the design pattern	
Rationale	Nature of the KSA of interest and how it is manifest	Warrant
Focal KSAs	The primary knowledge/skill/abilities targeted by this design pattern	Claim
Supported Benchmarks	Benchmarks in the MCA-II test specifications corresponding to Minnesota Standards that this design pattern supports (specific to the MCA-II context)	Claim
Additional KSAs	Other knowledge/skills/abilities that may be required by tasks motivated by this design pattern	Claim, if relevant; Alternative Explanation, if irrelevant
Potential Work Products	Features of work products that encapsulate evidence about Focal KSAs	Data concerning students' actions
Potential Observations	Things students say, do, or make that can provide evidence about the Focal KSAs	Data concerning students' actions

[6] The design pattern attributes shown here differ slightly from the presentation in Mislevy et al. (2003). First, this table omits some less central attributes that appear in the extended version of the design pattern structure discussed there. Second, two additional attributes have been added specifically to support task design for the MCA-II: Science Assessment.

- *Supported Benchmarks* indicates those benchmarks from the MCA-II test specifications that correspond to standards that this design pattern supports.
- *Narrative Structures* has been added in view of the particular structure of tasks in the MCA-II: Science Assessments. MCA-II science tasks are multi-item clusters that revolve around an incident, investigation, data set, or some other unifying context. These are called storyboards. Narrative structures are story frameworks that are analogous to basic plotlines for movies. Examples are Experiments, General-to-Specific, and Cause-and-Effect relationships

Characteristic Features	Aspects of assessment situations likely to evoke the desired evidence.	Data concerning situation
Variable Features	Aspects of assessment situations that can be varied in order to control difficulty or target emphasis on various aspects of the KSAs	Data concerning situation
Narrative Structures	Aspects of assessment situations that can be varied or combined to construct a storyboard outline	Data concerning situation

3.0 Observational Investigation

This section reviews the importance of observational investigation in science and defines the process of observational investigation. The outcomes of an alignment study are noted, which indicate that a design pattern to support authoring tasks on observational investigation can help bridge Minnesota and national content standards with the creation of tasks to assess these capabilities.

3.1 Observational Investigation in the Inquiry Process

No matter how one outlines the basic methods shared by all scientific disciplines, observation is a fundamental and indispensable cognitive skill in science (Millar, 1994; Tomkins & Tunnicliffe, 2001; Haury, 2002). Both the National Science Education Standard ((NSES); National Research Council, 1996) and the Minnesota Science benchmarks indicate that observation constitutes a method of scientific inquiry that is primary in certain scientific disciplines and at least present in other scientific disciplines, even when not primary.

Observation plays a vital role in investigations. In the hypothetico-deductive method that predominates in many natural sciences, observation constitutes the primary activity in the first step in a typical research cycle, followed by characterizations, hypotheses, predictions, and experiments (Popper, 1972). In many scientific areas, the primary means for systematic pursuit of knowledge come directly from observing and analyzing phenomena as the world presents them rather than experimentation, for in those cases it is difficult, if not impossible, to sample, control and manipulate variables as experimentation requires (Smith & Reiser, 2005). Such kinds of phenomena present one or more of the following characteristics.

- It may not be possible for researchers to experimentally replicate the investigations due to the fact that the interacting variables are too complex to be reproduced under controlled conditions (e.g., the origin of the universe).

- It may be impossible to randomly sample with enough statistical power to enable statistical hypothesis testing due to temporal or spatial constraints on sampling.
- It may be unethical to manipulate the variables of interest.

Examples from different science domains serve to illustrate the necessity of observational investigation in the inquiry process. The earth as a dynamic and evolving system is characterized by multiple interacting causal factors, non-linear relationships among subsystems and variables within those subsystems, partial historical records, and integral cyclical relationships among the underlying phenomena. It is often impossible either to control those variables due to the limitations of geologic time and space. Astronomy, one of the oldest nature sciences, uses the observations of the universe to confirm or refute existing theories of celestial bodies. It is unrealistic to manipulate the behaviors or natures of celestial bodies and geological phenomena such as volcanoes and earthquakes.

For the purpose of clarifying the above definition of observational investigation, we mention three things. Firstly, theory articulation is defined as people incorporating new evidence from observation to support or refute existing theories (Smith & Reiser, 2005). In K-12 education, the process of articulating a theory/model is more important than the application of the theory/model since articulation is an integral part of understanding the theory/model (Ohlsson, 1992). More specifically, students need to make sense of their observations by tying the observations to other aspects of the inquiry process, such as posing a question, collecting supporting data, developing appropriate explanations. Taking evolutionary theory as an example, although it is well known that animal populations change in order to adapt to the environment, often students will not know how the mechanism of natural selection operates in certain groups under particular conditions. Through observation of new behaviors or features of animals, students can articulate and elaborate this theory by comparing what they observe with what they know from the theory (Smith & Reiser, 2005).

Secondly, knowledge about some content domain is requisite for students conducting observational investigation. Familiarity with the relevant scientific knowledge can facilitate a student raising an appropriate question to be investigated, identifying relevant features of observations from irrelevant ones, collecting and displaying supporting or refuting data, and formulating an appropriate explanation. None of these things can be done without knowledge of the content domain. However, being familiar with content when the knowledge is biased, can have its own adverse impact since observation can be altered by belief (Fleck, 1935/1979). People tend to look for evidence that reinforces the thoughts they already possess. In this way, false views can lead students to seek one-sided evidence or distort their observations to confirm prior assumptions. Therefore investigators should be cautious when they encounter contradictory outcomes to their belief; it is always beneficial to double check the explanations being made for observations. We will see, in one of the variable task features, that one approach to assessing observational investigation capabilities is to pose a problem concerning the adequacy of observational data in a context in which the student already knows the answer—the point is whether the student can recognize inadequacies in the data or pose alternative explanations from the standpoint of the observations at hand. In this and similar ways, this design pattern aims to provide a general design space across different disciplines to generate tasks addressing aspects of reasoning skills in observational investigation, and can support the design of tasks to assess observation inquiry in different content domains.

Thirdly and most importantly, the biggest challenge of observational investigation comes from how to carry out the reasoning processes in context. Without training, students lack the tacit strategies with which experts design investigations, select and analyze relevant data, and develop observations into hypotheses and explanations (Smith & Reiser, 2005). Since the systematic, careful observation is often the defender of true science against pseudoscience, it is absolutely essential to make this underlying process in experts' minds as explicit as possible. Smith & Reiser (2005) propose an observational investigation model which introduces several strategies for observation and interpretation of animal behaviors: decomposing, comparing, identifying causes, and relating. Utilizing this idea, observational investigation can be summarized as

- Identification of aspects of phenomena to be investigated.
- Organizing and representing observations accordingly
- Developing hypotheses or explanations based on what is observed
- Determining ways of validating or falsifying the explanations, and revising them as unfolding information indicates.

3.2 Minnesota Science Standards and National Science Standards

A goal of the present project was to illustrate the use of ECD in the MCA-II: Science Assessment in ways that not only benefit the MCA-II but hold value in the larger science education and assessment communities more broadly. Ideally, the design pattern we create would support aspects of science learning reflected both in national standards and in Minnesota standards and benchmarks. To this end, we carried out a systematic alignment study among existing model-based-reasoning design patterns developed in the PADI project (Mislevy, Riconscente, & Rutstein, in press), Minnesota middle school science benchmarks, and the NSES (NRC, 1996). Unsurprisingly, science inquiry skills are highlighted in both science education standards.

The NSES (NRC, 1996) emphasizes the importance of unifying concepts and processes being shared by different scientific disciplines because they provide schemas that help students understand natural phenomena both within and across areas (p. 105). This unifying theme is also implied in Strand I of the Minnesota Academic Standards for Science, "Nature and History of Science."

More specifically, NSES stresses the ability to conduct scientific inquiry and understanding about it across contents and grades (p. 106). The role of observation in inquiry is underscored. In the earliest grades K-4, students are required to use simple instruments to observe evidence and then develop explanations (NSES, pp. 122-123). In middle grades 5-8, students should be able to conduct systematic observation by using appropriate tools and techniques, including computers, in order to base and differentiate their explanations from what they observed (NSES, p. 145). In high school, students are expected to be able to design and conduct an investigation in which students can organize and display data by means of various technologies and mathematics, and then formulate and revise scientific explanations and models based on observed evidence and logic (NSES, pp. 175).

Our alignment study showed that the Minnesota Academic Standards for Science also emphasize inquiry skills. They too expect that students be capable of observing at different levels for different grades. In grades 3-5, students should be able to raise a question to be investigated scientifically, make observations through simple tools, and collect and present data to support scientific understanding. In grades 6-8, students are supposed to be able to conduct observational investigations with systematic observations, to carefully collect relevant evidence, and to develop logical hypotheses and explanations. In high school, students are required to differentiate between observational and. experimental methods, to determine a testable question, to plan an investigation, to apply mathematics and models to analyze data, and to make evidence-based conclusions. The Minnesota requirements for observational investigations differ across content areas and grade levels even as they embody the same theme, by incorporating increasingly technical and sophisticated knowledge and skills. At the same time, the models and processes in the content strands (Physical Science, Earth and Space Science, and Life Science) that would be involved in investigations become correspondingly more complex.

Another finding from the alignment study is that the *Narrative Structure* attribute of design patterns noted above is reflected in the test specifications document[7] that is derived from the Minnesota Standards, in the form of “content limits.” The test specifications go beyond the statements of standards themselves, by further suggesting the kinds of reasoning and some of the features of tasks that are appropriate to include on the MCA-II to assess students at the given grade levels. Some narrative structures are implied in the content limits, and others are explicitly articulated. For example, a content limit for Grade 8 benchmark 8.I.B.1 in the History and Nature of Science strand states that gathering evidence to prove that continents move constitutes a demonstration of the knowledge that scientific investigations involve the common elements of systematic observation, careful collection of relevant evidence, logical reasoning, and innovation in developing hypotheses and explanations. Thus this content limit and its relationship to its benchmark indicate two narrative structures: “topic with examples” and “change over time.” To take another example, the narrative structure “specific to general” is clearly specified in Grade 8 benchmark 8.I.B.2, which requires students describe how scientists can conduct investigation in a simple system and make generalizations to more complex systems. Two more specific examples are used in its content limits: observations of the impact of penicillin on bacteria can lead to the generalization that penicillin can cure certain illnesses and observations of convection can help students study weather patterns. These examples support the project’s decision to include a special kind of variable task feature, narrative structures, as an attribute in its own right in the new design patterns in order to support task developers particularly as they create the ‘storyboards’ within which tasks are contextualized.

[7] *Minnesota Comprehensive Assessments Series II (MCA-II): Test Specifications for Science*. http://education.state.mn.us/mdeprod/groups/Assessment/documents/Report/006366.pdf

4.0 Design Pattern for Observational Investigation

This section presents the Observational Investigation design pattern and illustrates some of its attributes with exemplar tasks. The primary users of the design pattern are the storyboard and item writers who create the MCA II and would directly use the design pattern to support their work. Other users within the MCA-II context will be the Pearson professional test development team that structures the authoring and assembly of the MCA-II, trains the storyboard and item writers, and edits and refines their products as needed, and the Minnesota expert review panels who examine storyboards and items for content and appropriateness. Secondary user groups in Minnesota would be classroom teachers and curriculum developers, who would be able to use the design patterns to create classroom tasks and curriculum-embedded tasks that address the same standards that the MCA-II addresses, but in less constrained contexts. These uses lie outside the current project, but they constitute an opportunity to improve the alignment of instruction and large-scale accountability assessment at the level of the targeted science standards rather than at the level of specific test items. More broadly, educators and researchers in the science education community can also use it as a source of reference to understand how a design pattern helps writers produce tasks validly and efficiently for assessing students' scientific reasoning skills, such as those in observational investigations.

Table 2 presents a print-based "writer-friendly" version of the design pattern. It is intended to be brief so that storyboard and item writers find it easy to reference the central ideas. In its electronic form, many of these summarized points are accompanied by links to examples or more detailed discussion, for the user who wants to follow them up. In the table, *D* indicates the availability of further detail for an entry, and *E* indicates a hyperlink to an example. In this way, the user has a brief form of the design pattern immediately at hand, but has access to further detail should he or she want to use it. This feature is meant to offer further support particularly to storyboard and item writers who are new to the MCA, or be available for more experienced writers if they occasionally want to refresh their memories or see examples for inspiration.[8] The following discussion includes some of the additional material in those links.

Table 2. Writer-friendly Version of Design Pattern for Observational Investigation

Overview	This design pattern supports the writing of storyboards and items that address scientific reasoning and process skills in the context of observational (non-experimental) investigations. This design pattern can be used in conjunction with any science content strand. *D*
Use	This design pattern informs the writing of storyboards and items that evoke evidence about reasoning in the context of either student investigations or scientist investigations.
Focal KSAs	▪ Understanding why some scientific ideas need to be investigated through observational methods *D* ▪ Ability to analyze situations in which observational methods are more appropriate than experimental methods *D* ▪ Ability to distinguish between observational and experimental methodology *D* ▪ Hypothesis generation or evaluation about scientific phenomena that are subject only to observational testing and not to experimental testing *D* ▪ Hypothesis testing through observational methods *D* ▪ Ability to formulate conclusions, create models, and appropriately generalize results from observational, non-experimental research *D*
Supported Benchmarks	This design pattern can be used to support writing storyboards and items for the following benchmarks. ▪ Grade 8: 6.I.A.2, 7.I.A.2, 6,I.B.1, 7.I.B.1, 6.I.B.2, 6.I.B.4, 8.I.B.1, 8.I.B.2 ▪ High School: 9-12.I.A.3, 9-12.I.B.1, 9-12.I.B.6
Additional KSAs	▪ Content knowledge (may be construct relevant) ▪ Prerequisite knowledge from earlier grades ▪ Data collection and analysis ▪ Representational forms (e.g., graphs, maps)
Characteristic Features	Storyboards and items written using this design pattern will exhibit one or more of the following features: ▪ Focus on HNS (Strand I) benchmarks relating to observational investigations at the appropriate grade level ▪ Collection, presentation, and or representation of observational data ▪ Analysis and explanation of data; conclusion generation, given observational data ▪ Hypothesis generation, explanation, and/or modeling ▪ Model development, analysis, and testing

[8] An “in progress” version is currently available on line at http://design-drk.padi.sri.com/padi/do/AddNodeAction?NODE_ID=2167

Variable Features	The following features are variable depending on the storyboard and items: ▪ Content (strand) context E ▪ Qualitative or quantitative investigations ▪ Number of variables and complexity of their interrelationships ▪ Simple or complex investigations ▪ Data representation (e.g., patterns in geographically distributed phenomena via geospatial visualizations; patterns in data; similarities in specialized representations appropriate to the scientific phenomenon) E ▪ Student asked to interpret insufficient data about a fact already known?
Potential Work Products (MC questions, open-ended responses, figural responses)	▪ Generate or identify an explanation for observed findings E ▪ Modify or criticize problematic explanations. ▪ Identify or generate different observational settings that would help confirm or disconfirm hypotheses ▪ Identify or suggest other data that confirm or disconfirm a hypothesis for which evidence has already been identified from a different data source ▪ Identify or suggest potentially disconfirming observations that are stronger in being disconfirming that confirming ▪ Identify or suggest a process that may be occurring over time or across locations to produce observations (connected with a content-area) ▪ Fill in representation form (such as a graph, chart, or map) to express a hypothesis about what would be expected under a hypothesis E ▪ Critiques of peers (hypothetical in a standard assessment, real in classroom work) on their evaluations, explanations, or confirmation/disconfirmation procedures.
Potential Observations	▪ Plausibility / correctness of explanation for observed findings E ▪ Appropriateness of other potential observations for confirming or disconfirming hypothesis ▪ Accuracy in identifying the effects of an observed active phenomenon and how they may be a sign of a cause and effect relationship ▪ Strength of evidence of a suggested or identified situation where observation could help confirm or disconfirm a hypothesis ▪ Correctness or aptness of recognized patterns that ground a hypothesis E ▪ Accuracy in critiques of others (hypothetical in a standard assessment, real in classroom work) on the accuracy of what they identify in any of the above potential observations
Narrative Structures	▪ Investigation ▪ Specific to general E ▪ Parts to whole ▪ Topic with examples ▪ Change over time ▪ Cause and effect

Note: *D* indicates a hyperlink to extended detail or discussion of the entry, and *E* indicates a hyperlink to an example task that illustrates the point.

Another feature of the online version of the design pattern that cannot be fully demonstrated in this print version is associations among entries in different attributes. For example, the Additional KSA “Representational forms (e.g., graphs, maps)” is linked to the Variable Task Feature “Data representation” and the Potential Work Product “Fill in representation form to express a hypothesis about what would be expected under a hypothesis.” This means that the writer should be aware that the design choice of using a representational form as a work product induces a requirement for familiarity with that form on the part of the student—knowledge which, if the student lacked it, could lead to poor performance even if the science knowledge would have been sufficient. This may be perfectly appropriate, perhaps because the use of the representational form also satisfies the requirement of assessing another benchmark a storyboard must address. Or it may be the case that confounding a particular item with this additional skill demand is not desired, so a simpler form of work product would be preferable. The point is that the design pattern has made this design decision explicit to the writer, and support has been made available to help think it through.

4.1 Overview and Use

The Overview and Use attributes of this design pattern explain briefly that it is meant to support writing assessment storyboards and items that address aspects of reasoning in observational investigation in science. It is a content-neutral design pattern in the sense that it can be used in conjunction with any content in which such investigations can be carried out. Therefore, it supports writing tasks that address the nature and concepts of this aspect of scientific reasoning or assessing the skills in the context of a particular content-specific investigation.

The icon *D* in the Overview attribute indicates that a hyperlink in the electronic version provides further detail. The additional detail in this case is a discussion of the nature of observable investigations. This material corresponds to the warrant in Toulmin's argument structure, and provides the scientific educational and psychological principles behind the design pattern.

4.2 Focal KSAs, Supported Benchmarks, and Characteristic Task Features

The primary attribute of a design pattern is the Focal KSA. The Focal KSAs are the targets of inferences that assessors aim to make in an assessment, concerning some aspect(s) of proficiencies. A design pattern sometimes designates a group of related KSAs, as does this one. A task designer needs to decide whether to test all these KSAs as a composite or emphasize different aspects of them. The following section of variable task features discusses further how to implement this decision-making process. Focal KSAs are precursors to, in the sense of providing the educational meaning, the latent variable(s) in the measurement model in the CAF layer, be it as simple as a total score (what mix of KSAs is a set of tasks intended to evidence?) or a multivariate psychometric model (what aspects of knowledge or skill are intended to be evidenced in a collection of tasks that may require them jointly in various mixes?). A design pattern focuses on how to construct tasks that evoke evidence about the focal KSAs, and the determination of the nature and grain size of the analytic model is not determined at this phase of the design process.

Based on the analysis for observational investigation and motivated by the benchmarks in the MCA-II Test Specifications, this design pattern specifies as Focal KSAs a broad set of cross-disciplinary knowledge, skills, and abilities that students need to exercise when pursuing an observational investigation. As noted earlier, however, delineating these Focal KSAs is *not* meant to imply that these are skills that students possess in isolation of actual scientific content. Rather, they are aspects of the scientific activity that are pursued and are integral to the content being investigated. The KSAs encompass the indicated benchmarks shown in the design pattern at a more overarching level than the benchmarks or standards themselves (see Table 3), so that they are in accord more closely with the unifying themes and inquiry skills emphasized in NSES, and connect more strongly to the research base of observational investigation.

Table 3. Minnesota Benchmarks Related to Observational Investigations

Grade3-5:

- 3.I.A.I: The student will explore the use of science as a tool that can help investigate and answer questions about the environment.
- 5.I.A.1: The student will know that current scientific knowledge and understanding guide scientific investigation.
- 3.I.B.1: The student will ask question about the natural world that can be investigated scientifically.
- 3.I.B.2: The student will participate in a scientific investigation using appropriate tools
- 3.I.B.3: The student will know that scientists use different kinds of investigations depending on the questions they are trying to answer.
- 4.I.B.1: The student will recognize when comparisons might not be fair because some conditions are not kept the same.
- 4.I.B.3: The student will recognize that evidence and logic are necessary to support scientific understandings.

Grade6-8:

- 6.I.A.2: The student will explain why scientists often repeat investigations to be sure of the results.
- 7.I.A.2: The students will explain natural phenomena by using appropriate physical, conceptual and mathematical models.
- 6.I.B.1: The students will identify questions that can be answered through scientific investigation and those that cannot.
- 7.I.B.1: The student will formulate a testable hypothesis based on prior knowledge.
- 6.I.B.2: The student will distinguish among observation, prediction and inference.
- 6.I.B.4: The student will present and explain data and findings from controlled experiments using multiple representations including tables, graphs, physical models and demonstrations.
- 8.I.B.1: The student will know that scientific investigations involve the common elements of systematic observations, the careful collection of relevant evidence, logical reasoning and innovation in developing hypotheses and explanations.
- 8.I.B.2: The student will describe how scientists can conduct investigations in a simple system and make generalizations to more complex systems.

High School:

- 9-12.I.A.3: The student will recognize that in order to be valid, scientific knowledge must meet certain criteria including that: be consistent with experimental, observational and inferential evidence about nature; follow rules of logic and reporting both methods and procedures; and, be falsifiable and open to criticism.
- 9-12.I.B.1: The student will design and complete a scientific experiment using scientific methods by determining a testable question, making a hypothesis, designing a scientific investigation with appropriate controls, analyzing data, making conclusions based evidence and comparing conclusions to the original hypothesis and prior knowledge.
- 9-12.I.B.6: The student will give examples of how different domains of science use different bodies of scientific knowledge and employ different methods to investigate questions.

The design pattern lists summary forms of the Focal KSAs. The following paragraphs discuss the Focal KSAs in greater detail, along the lines that appear when a user follows the “Detail” hyperlinks in the online version of the design pattern.

Knowledge or *understanding* aspects of observational investigation include knowing…

- why certain scientific phenomena or hypotheses need to be investigated through other forms of observation besides experiments,
- that hypotheses can be generated based on observation, and
- how hypotheses can be tested through observing patterns and making conjectures about the focal phenomena.

The *reasoning* aspects concern the following phases of an investigation (which often take place in iterative cycles).

- Observational phase: These are strategies for observing and interpreting complex phenomena or behaviors. They include decomposing, comparing, and relating. Regarding decomposing: A complex phenomenon might consist of several constituent, related aspects. For example, to analyze the characteristic of a city’s climate, at least temperature and precipitation are necessary to consider. After studying these two indices over a year, one can infer its climate type. Regarding comparing: Unlike in experimentation, usually it is hard to draw causal relations based on a single observation. But comparing can provide a good way to help students narrow down hypotheses about an underlying cause. For example, Nain (Canada) and Aberdeen (England) are both located near the Atlantic Ocean at a comparable latitude. Why is Nain much colder than Aberdeen? To find the reason, a series of climate-related factors need to be studied and compared and the differences between the two locations must be considered. Regarding relating: Identifying common themes, patterns, or corresponding variables across multiple time points, locations, or examples is a step toward reasoning about underlying patterns and processes.

- Organizational phase: Building, comparing, and analyzing patterns in representational forms such as graphs, tables, maps etc. These aspects of an observational study are essentially the same as those used in experimental studies. Continuing the above example, to study a city's climate, temperature graphs and precipitation histograms are typical representational forms that are used to show climate patterns and can be compared with those of other cities.
- Hypothesis generation/explanation/modeling phase: After posing a question that guides the observation and analysis of relevant data, an explanation or hypothesis is developed to support or refute provisional theories about the underlying situation. Investigators need to be cautious about making causal explanations, because observational investigations highlight the key distinction between correlation and causation. In the context of observational studies, the correlation between two variables does not imply one causes the other. Unlike experimental studies, other possible factors that might influence the dependent variable can not be controlled or ruled out by design or randomization. A high correlation between two variables can actually be the coincident effect of a common cause, rather than a cause-effect relationship.
- Model testing phase: Here lies the major difference between observational and experimental investigations. Approaches in observational investigation include: reasoning from the proposed explanation to other situations and seeing if predictions are consistent with the model, developing alternative explanations, seeking predictions that would differ from those of the hypothesis, and looking for that evidence; controlling variables not by experiment but by comparisons; and building simulation models based on the hypothesis and seeing if the outcomes match observations. For example, to determine the accuracy of the summary for a city's climate in a year, one can check whether the prediction made for monthly-average temperature and precipitation in the next year are consistent with current findings. In contrast,

in an experimental investigation a researcher can generally repeat the experiment under essentially the same conditions many times to test a hypothesis or model.

After Focal KSAs are clarified as above, we need identify what kinds of tasks can evoke students' demonstration of the kind of knowledge skills and abilities necessary for observational investigations. Then we turn to another key attribute of design patterns, namely Characteristic Features of tasks. All assessment tasks motivated by this design pattern need to incorporate aspects of these characteristics in some form in order to evoke evidence about the Focal KSAs.

Since this design pattern is about observation instead of experimentation, the fundamental characteristic of the assessment tasks is that reasoning must be carried out without recourse to experimental methods (e.g., random assignment, control of variables, replicability). As an illustration, consider a Minnesota sample task on "Weather" (see Figure 3). In items 1-3 for this task, students are asked to explain the formulation of fog, wind, and moist convection, and observation—not experimentation—is the primary means to explore the phenomenon in these items (although laboratory experiments can in fact be carried out to test hypotheses about the underlying phenomenon in simplified settings). The "Weather" task will be referred several times in the rest of this report as a means of illustration.

Figure 3. Minnesota Item Sample ‘Weather’
(For interactive version of this task and many others, see http://etest.pearson.com/customers/Minnesota/mn/mca2scienceitem.htm)

Item 1:

On the way to school, students saw fog in low-lying areas. Students also noticed that the air was very calm, and there was little wind.

Media

Which sentence best explains the physical change that causes fog to form?

- **A.** Fog forms as water in the air reacts with nitrogen.
- **B.** Fog forms as water in the air goes from a liquid to a gas.
- **C.** Fog forms as water in the air reacts with oxygen.
- **D.** Fog forms as water in the air goes from a gas to a liquid.

Back | Reset | Go to... | Question 1 of 5 | Review | Next

Item 2:

Later that morning, students saw the flag blowing in the wind.

Media

Click the Next button to go on.

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Later that morning, students saw the flag blowing in the wind.

Media

Which statement explains why winds are often weaker at night and get stronger during the day?

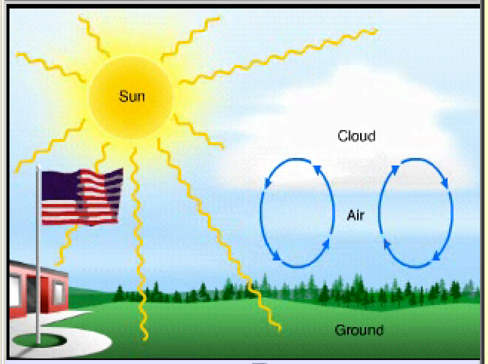
- ◉ **A.** Wind results from changes in the water vapor content of the air.
- ○ **B.** Wind results when rain or snow falls from clouds.
- ○ **C.** Wind results from unequal heating of the air.
- ○ **D.** Wind results where skies change from cloudy to clear.

Back Reset Go to... Question 2 of 5 Review Next

Item 3:

The energy that drives our weather is transferred through several processes.

Media



Click the Next button to go on.

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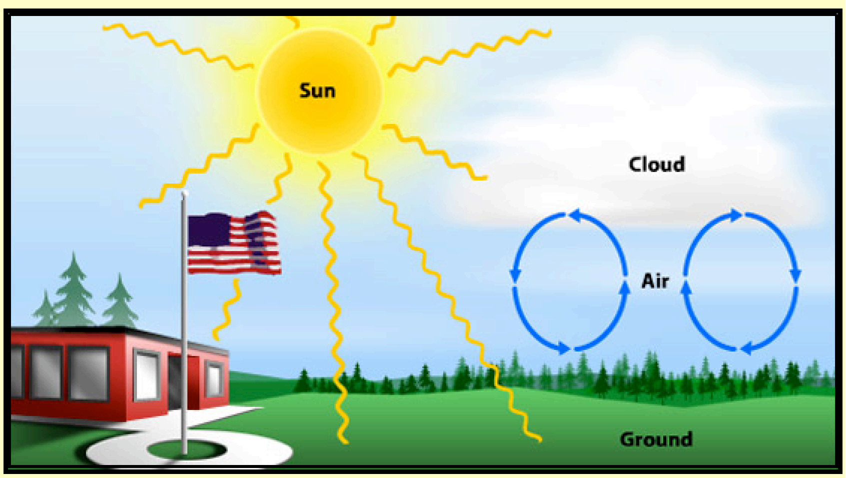
The energy that drives our weather is transferred through several processes.

Media

Choose the principal energy source that drives our weather.
Click on the diagram to put a "+" on this energy source.



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Item 4:

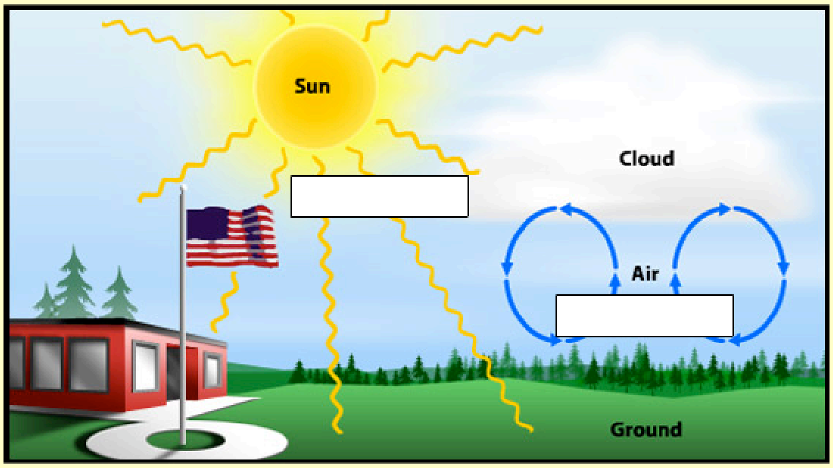
Energy is transferred through several processes. This diagram illustrates the various processes of energy transport that affect the Earth and its atmosphere.

Media

Use the processes listed below to complete the diagram.

Click on the process you want to select. Then click where you want to put the process.

- Convection
- Conduction
- Precipitation
- Condensation
- Radiation



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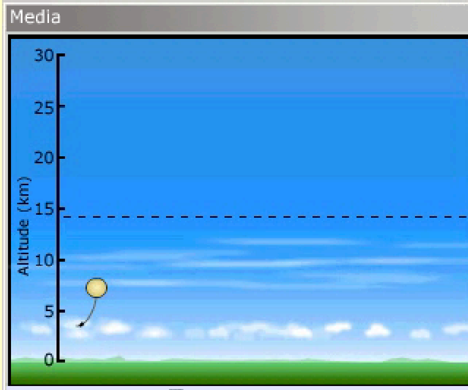
Item 5:

Weather balloons carry instruments that collect data as they rise through the troposphere into the stratosphere. Radios relay the data back to meteorologists.

Media



Describe a change that this weather balloon would record.

Type your response in the space below.

Explain what causes the change you describe.

Type your response in the space below.

Back | Reset | Go to... | Question 5 of 5 | Review | Next

Other types of Characteristic Features can be distinguished for each investigation phase, as noted below. In the online version, highlighting one of the entries in the Focal KSAs attribute will highlight the corresponding Characteristic Features, thus emphasizing to the assessment writer how assessment targets and task features are linked. We note that not all observational investigations have all the phases, and phases can appear iteratively. A given task or storyboard can focus on just one phase, a transition between phases, or work through multiple phases. This is a design decision that is up to the storyboard writer. Again, the design pattern does not make the decision, but it makes clear that there is a decision to be made and provides information to affect it.

- Observational phase: The characteristic features here are the presentation of observational data — either data, literal observation of a situation, or other kinds of representational summaries of observations. For example, the "Weather" task sample presents natural phenomena in graphical form to be observed by students. (We will discuss in the Variable Features section how writers can increase item difficulty or incorporate Additional KSAs by requiring students to interpret some scientific instruments, such as a thermometer or barometer, to obtain observational data.)
- Organizational phase: The characteristic feature of this phase is the need to move from observations that are not optimally organized to representations or summaries that are more amenable to highlighting patterns (e.g., in graphs, tables, maps, etc. or quantitative models). For example, to determine the long-term climate pattern for a city, it is better to transform the original daily data of temperature and precipitation to monthly-averages in order to summarize yearly characteristics.
- Hypothesis generation/explanation/modeling phase: Data are presented, and the tasks require the student to propose or select one or more hypotheses or explanation about the nature or mechanisms that underlie the observations. Question 5 in the "Weather" task requires students to explain the change that the weather balloon would record. If students understand the process of

energy transport in the atmosphere, they can anticipate the data trajectories inferred from the record of the thermometer and barometer and provide an appropriate explanation about the data changes.

- Model testing phase: Observations and a hypothesis are given. The student must reason about evidence to confirm/disconfirm the hypothesis, such as making predictions to other potential situations, relating it to another set of observations, determining a situation that would be consistent or inconsistent with the hypothesis, or proposing or selecting other phenomena that would tend to occur if the hypothesis were true.

4.3 Additional KSAs

Additional KSAs of a design pattern are the other knowledge, skills, and abilities that, at the writer's discretion, might be involved in a task that assesses the Focal KSAs. Categories of Additional KSAs include: prerequisite knowledge; content knowledge; familiarity with task tools, task expectations and formats; and cognitive and physical capabilities needed to apprehend, interact with, and respond to a task. This section discusses important Additional KSAs associated with creating tasks about Observational Investigation. Whether or not these KSAs are demanded by a task, and to what degree, will be affected by the writer's choice of Variable Task Features, which will be discussed in the following section. In the online version of the design pattern, a writer can use the highlighted linking option to bring out which Variable Task Features are involved in determining the demand for particular Additional KSAs.

Task developers need to make decisions about certain Variable Task Features as to how particular Additional KSAs will be or not be involved in a given task. Accommodations for students with special needs, for example, such as large print, or spoken rather than written response modes, circumvent Additional KSAs that most students have but that would act as irrelevant sources of difficulty to students with limited vision or mobility.

As we described previously, familiarity with content knowledge is necessary for students to reason about specific observational investigations. Potential content areas include Earth Science (including geology), Biology, Ecology, Chemistry, Astronomy, Anthropology, and other areas addressed in the Minnesota Academic Standards in Science in the ways they are reflected in the benchmarks in the test specifications document. The presence of content knowledge as an Additional KSA in the Observational Investigation design pattern emphasizes that the task designer must decide *what* content knowledge is involved and *how much* demand to place on it in the task. To assess inquiry capabilities, a task designer can choose to have low demand for content knowledge by embedding the inquiry item in a familiar everyday context or a scientific context from earlier grade levels. Alternatively, if the objective is to jointly obtain evidence about content (as specified by a targeted benchmark), then the demand for content knowledge can be appropriately high, and both the inquiry process and content knowledge are tested. In this approach, evidence about inquiry capabilities is conditional on content knowledge.

Additional KSAs can thus have positive, negative, or evidence-conditional effects on the validity of the assessment argument. They are included in the design pattern to alert the task developer to possible validity threats involving Additional KSAs.

In the case of the MCA-II, storyboards and items that are written by using this design pattern can require content-related KSAs that students should have gained in prior grades before they entered the grades that are covered on this test. Thus, all Grade 5 benchmarks in Minnesota Assessment Science Standards, as shown in Table 3, can be considered as Additional KSAs that are appropriate to include when task writers generate storyboards or items for students in middle or high school. The presumption is that they are not a primary source of difficulty to the student. That is, these are indeed skills or knowledge needed to solve the tasks, but they are not expected to be the source of poor performance among students who actually are proficient in the Focal KSAs.

Understanding how and where phenomena can be investigated experimentally is another kind of Additional KSAs in this design pattern since it can help students understand why they should use observation instead of experimentation. Even if students do not explicitly know the criteria of observational studies, the infeasibility of experimentation would drive them to seek another way to study phenomena. For example, the significance of temporal and spatial scale constraints on collecting data related to geological phenomena can make students aware of the difficulty of manipulating variables as required in experimentation.

Use of quantitative tools, such as modeling and statistical methods, can be helpful to conduct observational investigation. Students with good abstract thinking are able to map a real world situation into a symbolic model to be studied. Cummins, Ritger, & Myers (1999) provide a good example by using pumpkins, a flashlight, and acorn squash to represent the earth-sun-moon model, and a map and a flag as frames of reference on a rotating earth to study the relationship of objects in the solar system. Proficiency with quantitative tools (e.g., level of mathematics required) in a task is also an Additional KSA that a test developer needs to reason through when creating observational investigation tasks. These are Additional KSAs that, if a student does not have them, can lead to poor performance. In a classroom assessment, a teacher can include the use of levels of mathematics that he or she knows the students are familiar with, without threatening the validity of inference about their proficiencies with investigations. In a state-wide assessment, however, it may be necessary to target the level of mathematics lower – unless a given skill, such as reading a bar graph, is also one of the KSAs meant to be assessed. This example shows that different design decisions can be made for assessing the same Focal KSAs in different contexts, for different purposes, or in light of different background knowledge about students.

Use of measurement or data-collection methodology, such as observational protocols, instruments, and procedures related to observation in a particular domain, are also included as Additional KSAs. These can also be manipulated in the Variable Features attribute by task writers.

Familiarity with representational forms and their conventions of data can also affect the validity of the claims made for Focal KSAs.

4.4 Variable Task Features

Variable Features of tasks are a primary tool of task developers. They can take different values in order to adjust the difficulty of tasks, to shift the task emphasis on different aspects of Focal KSAs, or to incorporate different Additional KSAs.

The following types of Variable Features, but not limited to these, can be manipulated by task writers:

- Cognitive skill level. There are many ways used to describe the level of cognitive demand of tasks. The test specifications for the MCA-II employ Bloom's taxonomy levels (Bloom, Hastings, & Madaus, 1971). Their use of this feature includes three cognitive levels: A consists of knowledge, B of understanding, and C of application, analysis, synthesis and evaluation. The test specifications for the MCA-II indicate the range of cognitive levels that should be targeted for each benchmark.
- Content for the context of the investigation. As discussed in connection with Additional KSAs above, observational investigations involve some content. What content will be involved—everyday knowledge, content from earlier grades' standards presumed to be familiar, or content that is also at issue at

the grade level being assessed? Different content domains can be varied or combined as a context for tasks. In the MCA-II, content can be described in terms of the Minnesota Standards content classifications or test specification benchmarks.

- Qualitative or quantitative investigations. Qualitative research involves analysis of data such as verbal statements, pictures, videos, or objects. For example, in behavioral ecology, teachers use videos to study animals. Quantitative research deals with numerical data. For example, numerical data are required to test whether the ozone layer is being depleted. When quantitative data are used, it is possible to assess students' proficiency with data representations and concepts and with measurement techniques. Note that when forms of data or ways of working with them are involved, Additional KSAs are introduced if students need to apprehend or manipulate them. Either of these demands should be minimal so as not to introduce alternative, construct-irrelevant explanations for poor performance. Alternatively, the forms should be intended as targets of the assessment through benchmarks that the task is meant to address.
- The number of variables investigated and the complexity of their interrelationships. Complexity features in a situation include the number and variety of elements in the real-world situation, the complexity of their interrelations, the presence of extraneous information, and the degree to which elements have been stylized in order to make their identification easier. For example, in a regression analysis, the number of variables used for prediction can be varied. The students also can be asked to use graphical displays to explain why they believe the model fits or does not fit, or they can be asked to use statistical methods or graphical methods to justify their conclusions. For another example that is closer to K-12 education, task developers can increase the complexity of tasks by adding more celestial bodies of solar system into a study. Students can be required to study the Sun, the Earth, or the moon individually or jointly.

- Simple or complex investigations. A storyboard or task can focus on one phase or transition between phases or multiple phases of observational investigation as listed in the Characteristic Task Features section. A storyboard or task can focus on a particular content domain or involve multiple content areas, such as the use of chemistry to understand patterns in geology. Simple investigations have observations that are more closely and obviously aligned with the content models/principles/facts. More complex investigations are open to more alternative explanations, have outlier data, ambiguous observations, and so on. Students can be provided a clear initial question that makes their observation more purposeful. Or they can be asked to define their own questions from the observations. Students may be provided specific structured guidance in different phases of an investigation or allowed the freedom to investigate the problem in their own way. An on-demand accountability test such as the MCA-II usually uses a clearly specified problem, but more open-ended problem definition and ways of tackling the problem can be better suited to learning assessments in the classroom.
- The representational forms being used for data in the task. Does the initial presentation of observations involve literal observations or data summaries? If literal data are used, are measurements needed? Taking Item 5 in the "Weather" task (see Figure 3) as an example, if data collected by balloons are given, no matter what the verbal description of the change of temperature or atmospheric pressure or raw data from the measurement instrument may be additionally given, students should be able to develop explanations based on data provided if they understand the energy transformation in the atmosphere. Task writers can vary this feature to test different aspects of scientific skills or incorporate targeted Additional KSAs. For example, students may be required to read a measurement instrument in a graphical form to obtain raw data. For the organizational phase of an investigation, task writers also need to consider what form of data summary students can generate to display the observed pattern more clearly and thus

support their following explanation or hypothesis development. (This Variable Task Feature is thus linked to a corresponding Potential Work Product.) When students make an inference, they might need to consider the evidence across representational forms. Data transformation can also be used across different phases in the observational study if that is related to the intent of a task.

4.5 Narrative Structures

Narrative structures for the MCA-II storyboards are actually a Variable Task Feature, but one of sufficient importance to merit their own attribute in the design pattern. As noted earlier, narrative structures are recurring structures for organizing the flow of information and items in the contextualized sets of items that constitute an MCA-II Science task. For tasks that address Observational Investigation, five narrative structures were identified that lend themselves particularly well:

- Investigation. Investigation itself is a narrative structure, and of course it is a natural structure for storyboards and tasks that are required to assess students' knowledge of and capabilities with observational investigations.
- Specific–to–general and parts–to–whole. Specific characteristics of a phenomenon are presented, culminating in a description of the system or phenomenon as a whole. For example, students generalize about the effects of the damming of rivers by studying cases of specific rivers that have been dammed.
- Topic with examples. A given topic is presented using various examples to highlight the topic. For example, students are required to know some observed evidence that supports the Earth processes, such as the movement of tectonic plates, weathering, continental glaciation, and volcanic activity. (See benchmark 8.III.A.5 in test specifications document[9]). Or students can

[9] *Minnesota Comprehensive Assessments Series II (MCA-II): Test Specifications for Science*. http://education.state.mn.us/mdeprod/groups/Assessment/documents/Report/006366.pdf

compare and contrast data about earthquakes that have occurred during a specific range of years on different types of crustal plate boundaries in order to detect relationships between the characteristics of the earthquakes and the crustal plate boundary types.

- Change over time. A sequence of events is presented to highlight sequential or cyclical change in a system. Students might be required to discover the geological history of a landscape by observing the rock layers.
- Cause and effect. An event, phenomenon, or system is altered by internal or external factors. The task developer should be cautious in requiring students to make causal explanations in observational investigation. Only after ruling out other possible confounding factors that might affect the outcomes of phenomenon, can investigators draw inferences about observed evidence. For example, take a geologist's successful inquiry process as an example (NSES, pp. 1-5). The researcher proposed a possible hypothesis to explain the death of the forest near the shore of the state of Washington by excluding several alternative possibilities. Then he collected more sediment data to support his hypothesis.

4.6 Work Products and Potential Observations

The attributes of Work Products and Potential Observations in a design pattern concern how to capture students' thinking in terms of something they do or make, and identify the information that constitutes evidence about targeted aspects of Focal KSAs. In the online version of the design pattern, there are links between particular Work Products and observations because certain Work Products support identifying certain observations. (For example, when the National Board of Medical Examiners wants to assess how well a licensure candidate can palpitate an abdomen, the Work Product is the student's actual action sequence. When they want to know if the candidate can interpret the results of a palpitation, Work Products in the form of verbal statements or choices among alternatives can suffice.)

In the MCA-II, computer-based tasks are generated in three formats: multiple choice, open-ended response, and figural response. This is the structure of the Work Product. What is listed below and in the design patterns is the semantic content of the Work Product that can be considered as evidence of their reasoning skills in observation. They may be implemented in more than one of the structural forms available to the MCA-II.

- Generate or identify an explanation for observed findings.
- Modify or criticize problematic explanations.
- Identify or generate different observational settings that would help confirm or disconfirm hypotheses.
- Identify or suggest other data that confirm or disconfirm a hypothesis for which evidence already has been identified from a different data source.
- Identify or suggest potentially disconfirming observations that are stronger in being disconfirming that confirming.
- Identify or suggest a process that may be occurring over time or across locations to produce observations (connected with a content-area).

As an example in a particular domain, if tasks are designed to test students' understanding of plate tectonics in an observational investigation, possible Work Products can be: a model or simulation showing different types of crustal plate movements on different types of crustal plate boundaries; a model showing how different plates once fit together; drawings to show the edges of plate boundaries; and a puzzle showing how all the plates fit together.

Potential Observations are features of students' Work Products that constitute evidence of the Focal KSAs. They describe qualities, strengths, or the extent of work that tends to distinguish more or less capability on the whole or in selected aspects. Potential Observations for tasks addressing observational investigations include the following:

- Plausibility/correctness of an explanation for observed findings.
- Appropriateness of other potential observations for confirming or disconfirming an hypothesis.
- Accuracy in identifying the effects of an observed active phenomenon and how they may be a sign of a cause and effect relationship.
- Strength of evidence of a suggested or identified situation where observation could help confirm or disconfirm a hypothesis.
- Correctness or aptness of recognized patterns that ground a hypothesis.
- Accuracy in the critiques of others (hypothetical in a standard assessment, real in classroom work) on the accuracy of what they identify in any of the above Potential Observations.

Continuing the example of plate tectonics, Potential Observations could include the following:

- Accurate identification of earthquake-related effects and how they may be a sign of crustal movement.
- Identification of different types of volcanoes and where they typically occur on earth.
- Identification of sea-floor spreading areas.
- Identification of the "Ring of Fire" in the Pacific Ocean.
- Identification of plate boundaries.
- Description of the different types of faults and their motion.
- Identification of land masses that were formerly connected (Africa and South America).
- Accurate critiquing of "peers" on the quality of their observations of earth phenomena related to plate tectonics.

5.0 Discussion

Assessment tasks are situations constructed to elicit evidence about certain knowledge, skills, or abilities on the part of students. Just why the situations should do that, reasons why they might not, options for tuning them, and what to look for in performances and how to evaluate them, are all elements of an evidentiary argument. The best test developers reason in this way and produce tasks that ground arguments that are coherent and appropriate to their intended purposes. Evidence-centered design was developed as a way to make more explicit the different work that is being carried out in good assessment practices; to lay out the principles, provide language, and offer representational forms that can scaffold the work of the many parties involved in the development and use of assessments (Mislevy, et al., 2003).

Design patterns are one such tool. They are meant to support the long and somewhat mysterious step from a statement of standards or benchmarks to the production of specific tasks that elicit evidence about students' proficiencies with respect to those standards. It is at just this step that the talents of gifted test developers come into play and where novice test developers (including most classroom teachers and even many curriculum developers) have the hardest time. This is particularly true when the intended tasks are innovative as to format or use of technology, or address traditionally hard-to-assess proficiencies such as inquiry and model-based reasoning in science.

These, then, are the areas we are targeting in the present project in order to build design patterns that meet several characteristics:

- They address aspects of science that are at once hard–to–assess and central to the Minnesota Academic Standards in Science and MCA-II test specifications.
- They address aspects of science that are of broader interest to the science education and assessment communities, as reflected in current research and

in authoritative statements by groups such as the National Science Education Standards (NRC, 1996). In particular, we are looking toward inquiry in science and the unifying themes that include model-based reasoning and systems.

- They will immediately support the work of the task development teams for the MCA-II as they create storyboards and items for new versions of the assessment.
- In addition to supporting MCA-II test development, they will be broad enough to be useful for other purposes both within Minnesota (e.g., as support to classroom teachers for developing learning tasks) and beyond (e.g., for use by other states or entities, curriculum developers, and researchers).

Innovations to the original design pattern structure that have been developed in this project are a writer-friendly format to provide concise lists of attributes with links for additional discussion or examples (suggested in the textual form printed here, and available in the online illustration) and the highlighting of related entries across different attributes. Current work includes trying out the Observational Investigation design pattern with Minnesota test developers in offline talk-aloud studies, followed by actual use in operational test development work for the MCA-II, and the creation of additional design patterns similar to the model of the one discussed here.

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